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FINAL REPORT

Summary Section

Principal Investigator
Prof. Forrest S. Mozer

April, 1976

Series 17 Issue 35

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# Incoherent Scatter Radar Space Shuttle Feasibility Study

## SUMMARY

The incoherent scatter radar is a powerful tool which can simultaneously measure electron and ion temperatures, ionization density, and ionospheric bulk velocity. Such a radar decreases in effectiveness as the snr, signal to noise ratio, decreases. Small values for snr result from large distance between radar and target, low target density, and extraneous signals in the radar receiver which cannot be distinguished from the desired incoherent scatter return signal.

At present all incoherent scatter radar systems are ground based. They are relatively expensive because they require both high power and large directional antenna systems to achieve acceptable values of snr. Due to their expense, incoherent scatter radars are few, and most of the Earth's ionosphere is inaccessible to them. A system of incoherent scatter radars which would map the entire ionosphere to a height of several hundred kilometers would be extremely costly.[1]

The situation of ground based incoherent scatter radars may be contrasted with that of an orbiting incoherent scatter radar. In polar orbit, such a radar would eventually access the entire ionosphere. For a typical Space Shuttle orbit, much of the ionospheric region studied by ground based systems would be more closely approached by an orbiting system.[2] Also, many antenna orientations forbidden to ground based systems because of large unwanted ground reflected signals would not be forbidden

to an orbiting system. The added flexibility of an orbiting radar could be particularly useful in auroral regions.[3] Lastly, if scientific experiments, designed to affect the nearby ionosphere, were mounted on the same space vehicle as an incoherent scatter radar, the orbiting radar could be a valuable diagnostic tool whereas a ground based radar could not.

Because of the advantages of an orbiting versus a ground based incoherent scatter radar system, the feasibility of mounting a radar system on the Space Shuttle was studied. The study consisted of two parts. The first, conducted at the University of California at Berkeley, considers theoretical aspects of incoherent scatter radar. It concludes that the random error in the measurement of plasma density or the line-of-sight velocity is proportional to

$$\left[\left(1 + \frac{1}{snr}\right)^2 + \left(\frac{1}{snr}\right)^2\right]^{\frac{1}{2}}$$

From this expression, a change in system operating conditions from $snr = \infty$ to $snr = 2$ results in an increase of the random error by a factor of 1.5, while for $snr < 1$, the measurement error varies as $(snr)^{-1}$.

Thus, in designing an incoherent scatter radar system, an objective of $snr = 2$ is desirable but values of snr greater than 2 have small effects on the measurement error.[4]

The second part of the feasibility study, conducted by Stanford Research Institute, mainly explores the engineering problems associated with implementation of an orbiting incoherent scatter radar having $snr \approx 2$.

These include antenna and power requirements as well as various methods of maximizing spatial resolution and snr. Also considered is the problem of interfering groud-reflected signals and possible interference from auroral semicoherent clutter.[5] The S. R. I. study concludes that, though an incoherent scatter radar has scientific merit and is technically feasible, an orbiting system may be extremely costly. Problems of antenna design and deployment require further study in order that antenna costs may be evaluated.[6] In addition, the extent of semicoherent clutter in the ionosphere is not known. The usefulness of incoherent scatter techniques will be greatly reduced if such clutter is abundant.[6]

The extent of semicoherent clutter can best be determined by flying a coherent scatter radar on the Space Shuttle. Such a radar would require a smaller antenna system and less power than an incoherent scatter system. If an incoherent scatter radar is to be flown on the Space Shuttle, a coherent scatter instrument should be flown first. Such a system would not only ellucidate the scientific usefulness and cost effectiveness of an incoherent scatter radar, it would provide valuable scientific information as well.[7] With careful design, a coherent scatter radar might be incorporated into the incoherent scatter system if such a system were deemed cost effective.

References

1. See S.R.I. Report, Section V and VI

2. See S.R.I. Report, Section V

3. See S.R.I. Report, Section V

4. See U.C.B. Report, Part II

5. See S.R.I. Report, Section V

6. See S.R.I. Report, Section VII

7. See S.R.I. Report, Section VI